PATENT SPECIFICATION (11) 1412250

1412250

(21) Application No. 59925/72 (22) Filed 28 Dec. 1972
(31) Convention Application No. 1057/71 (32) Filed 28 Dec. 1971 in (19)
(33) Japan (JA)
(44) Complete Specification published 29 Oct. 1975
(51) INT CL² H01J 61/92 61/42
(52) Index at acceptance
H1D 12B47Y 12B4 35 5G 5J 5M1A 5M1BY 5M1D 5M1Y 5MY

(54) GAS DISCHARGE DISPLAY DEVICES

(71) We, FUJITSU LIMITED, a Japanese Corporation, of No. 1015 Kamikodanaka, Nakahara-ku, Kawasaki, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to gas discharge display devices.

Gas discharge display devices, often termed plasma display panels, have been proposed mainly for use in displaying letters or numbers, but application of such devices to the display of pictures with half-tones has been receiving attention in the light of proposals for producing different degrees of brightness displayed by means of such devices. Three general methods that have been proposed for producing different degrees of brightness are as follows.

The first is a method of controlling the frequency of discharge by varying selectively the frequency of a sustaining signal applied to a discharge plasma display panel as described in an article entitled "A Gray-Scale Technique for a Plasma Display Panel and Similar On-Off Devices", by M. Dejule et al, in "Society for Information Display International Symposium, 1971 May 4—6". Application of this method involves rather complex control circuitry, and difficulties may be encountered with instability of operation.

The second method is based on the initial construction of a gas discharge display device so as to give the picture elements individual weightings as regards the luminous brightness that will be produced by discharge therein. For further explanation, reference may be had to United States Patent Specification No. 3,559,190, more particularly Figure 21. However, this method can result in a decrease in resolution, because of a necessity to use enlarged picture elements, and the distinction between the degrees of brightness obtained may not be sufficiently clear.

The third method involves stacking a plurality of discharge panel units together with appropriate optical attenuating films and obtaining the desired multi-tone display by the combination of respectively attenuated discharge light from the different discharge panel units. Such a method is proposed in an article entitled "Gray-Scale Plasma Display" by D. T. Ngo, in "Society for Information Display International Symposium 1971 May 4—6, IDS, 1971, pages 100—101". However, difficulties due to parallax have been experienced with this method.

According to the present invention there is provided a gas discharge display device, comprising a plurality of panel-form arrangements each providing a two-dimensional array of gas discharge locations which can be addressed individually, to establish electrical discharge thereat, by means of electrodes of the arrangements, one of the said arrangements being provided with area of luminescent material which are respectively at or respectively adjacent to the gas discharge locations of that one arrangement, and the said arrangements being assembled together in a stack, with the addressable gas discharge locations of the or each other one of the said arrangements disposed respectively adjacent to the said areas, so that excitation of any chosen one of the said areas, selectively to different degrees of luminescence, can be brought about by establishing discharges selectively at those particular respective discharge locations of the said arrangements that are adjacent to the chosen area, thereby enabling a visible output display of differing degrees of brightness to be produced by means of the device.

Thus, in one embodiment of the present invention the parallax difficulties of the aforesaid third method can be minimised by providing the required display by excitation of phosphor materials contained in a single one

[P

of the respective discharge spaces of a stack of plasma display panels. Such a stack can include, between adjacent display panel units, control elements primarily responsible for differences in the volume of discharge radiation reaching the phosphor materials from the respective discharge spaces, particularly when the exciting radiation is constituted mainly by the ultraviolet or infra-red content of the luminous discharge spectra.

Reference will now be made, by way of example, to the accompanying diagrammatic drawings, in which:

Figure 1 shows a cross-sectional view of part of a first gas discharge display device embodying the present invention,

Figure 2 is a graph,

Figure 3 shows a cross-sectional view of part of a second gas discharge display device embodying the present invention, and

Figure 4 shows schematically, in plan view, a modified form of the Figure 3 embodiment, still embodying the present invention.

The gas discharge display device in Figure 1, generally indicated by the reference numeral 10, comprises a stack of three discharge panel arrangements 20, 30, and 40, considered from the rear (at the top of Figure 1) towards the front of the device. The rearmost discharge panel arrangement 20 is provided between a comparatively thick back-plate 21 and an intermediate base-plate 22 which serves as a first ultra-violet ray absorption layer, both of the plates 21 and 22 being made of glass, and the discharge space 23 between the two plates is filled with a gas mixture of helium (He) and xenon (Xe). The opposing respective surfaces of the plates 21 and 22 are provided respectively with X-electrodes 25 (only one of which can be seen in Figure 1) and Y-electrodes 26 disposed in crossing relationship with the X-electrodes so as to provide an addressable two-dimensional array of gas discharge locations, and the electrodes are covered with respective dielectric layers 24.

The second discharge panel arrangement 30 is provided between the intermediate base-plates 22 and a second intermediate base-plate 32 which functions as a second ultra-violet ray absorption layer. The discharge space 33 of the arrangement 30, between the plates 22 and 32, is again filled with the gas mixture of helium and xenon. The addressable discharge locations in the discharge space 33 are defined by means of X-electrodes 35 and Y-electrodes 36 which are provided respectively on the mutually opposed faces of the plates 22 and 32 and are covered with respective dielectric layers 34.

The foremost discharge panel arrangement 40 is provided between the second intermediate base-plate 32 and a front plate 42, and also has its gas discharge space 43 filled with a gas mixture of helium and xenon. X-electrodes 45 and Y-electrodes of the front discharge panel arrangement 40 are provided respectively on the mutually opposed surfaces of the plates 32 and 42, and are covered with respective dielectric layers 44.

Phosphor dots 47 are provided on the surfaces of the dielectric layers 44, exposed in the discharge space 43, adjacent respectively to the addressing electrode positions as is evident from Figure 1. It will be appreciated that the addressable discharge locations of the respective panel arrangements 20, 30, and 40, are placed adjacent to one another, so that the respective addressable arrays of discharge locations are in register with one-another as seen from the front of the device (the device in practice is, of course, much thinner than it appears in Figure 1).

In the embodiment of Figure 1 the material of the phosphor dots 47 is of the kind that is sensitive to ultra-violet radiation, so that the degree of luminous brightness exhibited by the phosphor spots will vary with the ultra-violet radiation flux incident thereon. The material of the phosphor dots 47 may be of the green luminous type, such as zinc-oxide or zinc-silicate, for example, and the general relationship between luminous brightness (measured along the ordinate axis) and the incident flux (or "volume") of exciting ultra-violet radiation (measured along the abscissa axis) is illustrated by the graph of Figure 2.

In the gas discharge display device 10, when a firing voltage is set up between that one of the X-electrodes 25 and that one of the Y-electrodes 26 which cross one-another at the discharge location A1, so as to address the point A1 of the first display panel arrangement 20, the resulting electrical discharge established at the location A1 produces ultra-violet radiation which, after passage through the ultra-violet-radiation absorption layers constituted by the intermediate base-plates 22 and 32, excites the phosphor dots 47 at the location C1 (in register with the location A1) in the gas space 43, so that these particular phosphor dots 47 are caused to luminesce visibly with the degree of brightness that is indicated by L2 in Figure 2. Similarly, when the discharge location B2 of the second discharge panel arrangement 30 is addressed, the resulting ultra-violet radiation flux, being attenuated only by the plate 32, excites the phosphor dots 47 at the adjacent location C2, in the gas space 43, to luminesce visibly with the degree of brightness indicated by L3 in Figure 2. It will be appreciated that, since the exciting radiation flux reaching the location C2 from the discharge at the adjacent

location B2 is greater than that reaching the display location C1 from a similar discharge at the addressable location A1, L3 is higher than L2. Furthermore, by employing appropriate address electrodes 45 and 46 of the third discharge panel arrangement 40 to establish a discharge at the location C3 in the arrangement 40, the ultra-violet radiation due to this discharge will bring about direct excitation of the phosphor dots 47 adjacent thereto so as to produce a visible output with the even higher degree of brightness indicated by L5 in Figure 2.

It will accordingly be appreciated that excitation of the phosphor dots 47 by means of appropriate combinations of discharges in the three discharge arrangements 20, 30, and 40, can be used to produce a display exhibiting eight different degrees of brightness L1 to L8. By adding another discharge panel arrangement to the stack so as to produce a four-layer construction, the ability to produce a sixteen-tone display could be achieved.

As an alternative to the gas mixture of helium and xenon filling the discharge spaces 23, 33, and 43, a gas mixture of helium (He) and krypton (Kr) may be used. Each of these gas mixtures gives a reasonably low firing voltage, and provides an emission spectrum which is concentrated in two main regions, one being an ultra-violet region and the other being an infra-red region, with relatively little visible radiation being emitted in the spectral region between these two main regions. The three discharge spaces 23, 33, and 43 need not be independently enclosed as shown in the drawing. Instead, a construction in which these spaces are in communication with one another, for example by way of holes in the intermediate base plates 22 and 32, could be preferable from the point of view of simplifying the manufacturing process. With regard to the problem of unwanted "cross-talk", i.e. the excitation of the phosphor dots 47 by discharges at display locations not respectively adjacent thereto (for example, excitation of a luminescent display at the location C3 by radiation from a discharge at the location A1), this problem is not of great practical significance because of the fact that the overall thickness of the operative portions of the construction illustrated in Figure 1 (i.e. the separation of the plates 21 and 42) can in practice be made less than 5 millimetres, the thickness of each of the discharge spaces 23, 33, and 43 being of the order of 200 microns. However, in order to reduce the danger of cross-talk even more, it is desirable to use a cell spacer formed with an array of holes positioned respectively at the discharge locations between intersecting X and Y address electrodes in each of the spaces 23, 33, and 43. At the same time, to inhibit diffusion of ultra-violet rays in directions other than perpendicular to the main surfaces of the plates, the intermediate base plates 22 and 32 may be constituted by optical guide plates, for example comprising optical fibres.

In the embodiment of Figure 3, like components are given the same reference numerals as in Figure 1. In the Figure 3 embodiment, however, the discharge regions 23, 33, and 43, contain respective cell spacers 28, 38, and 48, which are in the form of plates having small holes formed therethrough at the respective addressable discharge locations. Thus the discharge locations in each discharge region are divided optically from one another by the material of the cell spacers. The intermediate base plates 22 and 32 are in this embodiment constituted by optical fibre plates. Further, in this embodiment the phosphor dots 47 are provided only on the rearward one of the two dielectric layers 44, being positioned respectively at the addressable discharge locations of the front discharge panel arrangement 40.

This particular distribution of the phosphor dots is very effective in minimising parallax difficulties.

As described above, ultra-violet radiation absorption layers can be simply provided by suitable construction of the intermediate base plates 22 and 23, for example of soda-lime glass, or alternatively (for example as in the Figure 3 embodiment) the function of ultra-violet radiation absorption can be performed primarily by the dielectric layers covering the X and Y electrodes, when these layers are made of suitable material. Another possibility, of course, is to provide an additional ultra-violet radiation absorption layer as part of the stack of arrangements making-up the complete device.

Whilst the above description is concerned with devices for unipolar display, the principles illustrated can be adapted, to provide a multi-colour display, as illustrated in Figure 4. The construction illustrated in Figure 4 differs essentially from that of Figure 3 only in the distribution of fluorescent material. Whereas the fluorescent material is provided in the form of simple phosphor dots, each of the same material, in Figure 3, Figure 4 shows instead the use of three kinds of fluorescent material, provided as respective lines R, G, and B, of substances which emit red, green, and blue visible light respectively when excited. These lines R, G, and B, are arranged alongside respective X electrodes 45, and are disposed one after another, in cyclically repeated manner, in a direction along the Y electrodes. Thus, each picture-display element in this case is defined by means of one Y electrode 46 and three X electrodes 45 (R. G. B), and

whereas different degrees of brightness can be obtained at a picture-display element by selectively addressing respective panel arrangements of the stack forming the discharge device, different colours at the respective picture-display elements can be obtained by appropriate selection among the three X electrodes at each of the picture-display elements concerned.

As a modification of the above-described embodiments, it is possible to make use of infra-red rays in the discharge emission spectra for exciting the fluorescent materials. In this case, infra-red radiation absorption layers may be provided between the discharge panel arrangements and luminescent phosphor materials which emit visible rays when excited by infra-red radiation, are used to provide the output display. The infra-red rays, being invisible, do not directly constitute a visible output of the device.

Another modified form of the device employs discharge panel arrangements of the direct discharge type, having the addressing electrodes exposed in the discharge space. In another embodiment, the X and Y electrodes of each discharge panel arrangement, although insulated from one-another, are provided on the same wall surface of the arrangement as one another, i.e. to one side only of the discharge space, rather than being provided at opposite sides of the discharge space as is the case in Figures 1 and 3. In an embodiment of the present invention, an increase in the number of tones, or degrees, of brightness obtainable can be achieved by operating the discharge panel arrangements with alternating sustaining signals having different respective frequencies if desired, and it is also possible to construct an embodiment in which the composition of the enclosed discharge gas is different in the different discharge panel arrangements, so as to provide different light outputs from respective discharges in these discharge panel arrangements.

WHAT WE CLAIM IS:—

1. A gas discharge display device, comprising a plurality of panel-form arrangements each providing a two-dimensional array of gas discharge locations which can be addressed individually, to establish electrical discharges thereat, by means of electrodes of the arrangements, one of the said arrangements being provided with areas of luminescent material which are respectively at or respectively adjacent to the gas discharge locations of that one arrangement, and the said arrangements being assembled together in a stack, with the addressable gas discharge locations of the or each other one of said arrangements disposed respectively adjacent to the said areas, so that excitation of any chosen one of the said areas, selectively to different degrees of luminescence, can be brought about by establishing discharges selectively at those particular respective discharge locations of the said arrangements that are adjacent to the chosen area, thereby enabling a visible output display of differing degrees of brightness to be produced by means of the device.

2. A device as claimed in claim 1, wherein the said areas are arrayed over one face of a main wall of the said one arrangement, the gas in which such discharges are produced in the one arrangement when it is in use being contained between the said one face and an opposing face, of an opposite main wall, of the said one arrangement.

3. A device as claimed in claim 1 or 2, wherein the construction of the said stack is such that differences in the degrees of said luminescence due to radiation from like discharges established respectively at the respective adjacent discharge locations of the different arrangements are due to differences in the flux values of the exciting radiation, from the respective adjacent discharge locations, due primarily to the fact that radiation from one of the adjacent discharge locations has to pass through an absorbing wall, assembled in the stack, through which radiation from another of the adjacent discharge locations does not have to pass in order to reach the chosen area.

4. A device as claimed in claim 3, wherein the said luminescent material is excitable, to emit visible radiation, primarily by ultra-violet radiation, and the said absorbing wall is preferentially absorbent to ultra-violet radiation.

5. A device as claimed in claim 3, wherein the said luminescent material is excitable, to emit visible radiation, primarily by infra-red radiation, and the said absorbing wall is preferentially absorbent to infra-red radiation.

6. A device as claimed in claim 3, wherein the said wall member comprises an intermediate member separating the gas-containing region of a first such arrangement from that of the next.

7. A device as claimed in any preceding claim, wherein said areas of luminescent material are arrayed over one wall surface only of the said one arrangement and the device has no areas of luminescent material elsewhere.

8. A device as claimed in claim 7, wherein the said one arrangement is arranged at one end of the said stack, so that the said visible output display can be viewed at that one end, the said one wall surface being at the rear of the gas-containing region of the said one arrangement as so viewed.

9. A device as claimed in any preceding claim, wherein the said areas of luminescent

material are provided by lines of respective substances which, when excited, emit light of different respective colours.

10. A device as claimed in claim 9, wherein the said lines of the respective luminescent substances are arranged alongside one another, one after the other in cyclically repeated manner in a direction transverse to the lines.

11. A device as claimed in any preceding claim, wherein the gas discharge locations of each of the arrangements are separated from one another by spacing means provided in the gas-containing region of the arrangement.

12. A device as claimed in any preceding claim, wherein the stack includes plates comprising optical fibres arranged for directing radiation, from such discharges, preferentially in the stacking direction.

13. A gas discharge display device, substantially as hereinbefore described with reference to Figure 1 or 3 of the accompanying drawings, or with reference to either of Figures 1 and 3 when they are modified in accordance with Figure 4 of the accompanying drawings.

HASELTINE, LAKE & CO.,
Chartered Patent Agents,
Hazlitt House,
28, Southampton Buildings,
Chancery Lane,
London, WC2A 1AT,
Agents for the Applicants.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1975.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1412250 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

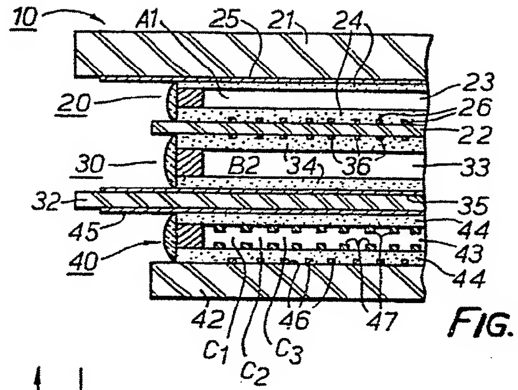

FIG. 1.

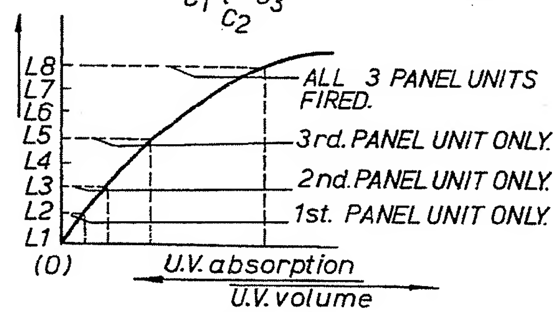

FIG. 2.

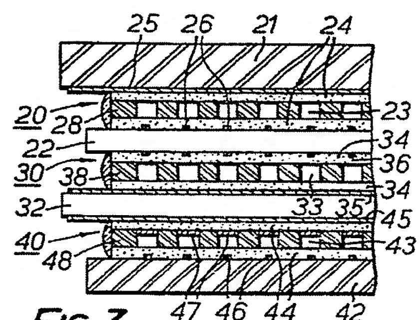

FIG. 3.

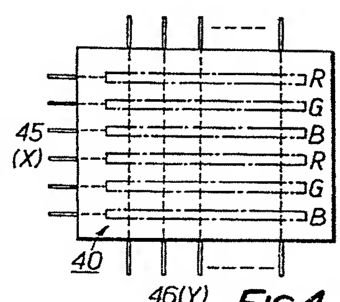

FIG. 4.